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THE ETIOLOGY OF ASTIGMATISM.

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It is amazing that ophthalmic science, especially that of Europe, has never concerned itself with the question of the origin or the effects of astigmatism. The least curiosity as to these matters would have been worth a thousand times all the study of a thousand text-books, covering the mathematics of the condition. The causes of astigmatism are thus epitomized by Norris and Oliver:

"Traction on the cornea, as seen in peripherally situated cicatrization wounds, either accidentally or purposely made, superficial tumor-growths at the corneal limbus, symblepharon, and pterygia, all may be the production of astigmatism. Direct and indirect pressure on the cornea or the sclerotic, as, for example, from new growths that are situated either in the orbit or in the eyelids, and spasmodic contraction of the orbicularis muscle, are said to give rise to corneal astigmatism. In contradistinction to this, irregularities of the tunics at the posterior pole of the eye may produce an astigmatism by faulty curvatures of that portion of the retinal sheet which is situated at the macular region. Astigmatism is also said to be caused by intraocular pressure and tonic contraction of the exterior ocular muscle-groupings. The variety that is produced by lid-pressure is either a temporary form of the regular type, or, more frequently an irregular one of meridional character. In this connection it must not be forgotten that a spastic condition of a series of extraocular muscles, as is occasionally seen in some types of nerve disease, may give rise to temporary forms of the condition."

Norris and Oliver supposably summarize the ophthalmic knowledge of the day; and this series of obfuscating statements may therefore be taken as illustrative of the vagaries and indetermination of professional opinion upon the subject. There is not a word or suggestion in it which helps the student of physiology or of medicine, or the practising physician and

refractionist, to understand the origin of this tremendously important form of ametropia. The baneful effect of anatomic pathology to the exclusion of physiologic pathology is seen in every line quoted. Wounds, tumors, inflammation, tumors, spasms, tumors, mysteries, tumors, nerve-diseases, tumors—how do these things, found once in a million cases of astigmatism, help us to understand the cause in 999,999 cases, where tumors, inflammations, new-growths, and spasms have not existed? Macular malcurvature is also listed, without a statement as to the size of the image of a test-letter at the macula. Intraocular pressure, the true cause of corneal symmetry, is also adduced,—a cause that acting alone would reduce corneal asymmetry or make it impossible. The actions of the external ocular muscles almost surely, have at best only a secondary and subordinate role in causing astigmatism. The one real and dominating cause, lid-pressure, is befoggingly called “an irregular form of meridional type,” or a “temporary form of the regular type.” But what is this regular type? Evidently, tumors and wounds and the rest, judging from the list above. But if not, there is not the least hint of an explanation either of the cause or nature of this all-important “regular type.” Beauty, sang the poet, is its own excuse for being, and so evidently is astigmatism. It is, because it is. Johnson rebuked Boswell severely for asking why a pear is shaped as it is and an apple of a different shape. “God wills it,” “Fate rules us all,” “Allah is Allah,” are quite as satisfying explanations, either of astigmatism or of the world, and of our destinies in it. If we turn to other text books we find the explanation of the most to consist in the platitudinous “congenital or acquired” which is equally amusing and unsatisfactory. If congenital, what caused the failure to secure an all-desirable corneal symmetry? If acquired, how and why? Astigmatism of the “unglassed” is wrecking the lives or happiness of millions of people, and necessitating an expense of millions of dollars by those who wear glasses. Its nature and cause therefore become highly important matters. One will occasionally find a statement seemingly made in the interests of the tenotomists that the tensions, malinsertions, or abnormalisms of the external ocular muscles are the cause of corneal malcurvature. But when one asks how this is possible or probable, no answer can be found. The shorter radius of curvature in the vast majority of cases is the vertical, but if there is any excess of tension of one set of muscles over the other it is that of the combined internal and external over that of the combined su-

perior and inferior; and this would cause the lesser curve to be horizontal. Surely then the role of the external muscles is nil, or subordinate and secondary. It seems probable that the internal and external recti muscles act to neutralize the tendency otherwise caused of the vertical meridian of the cornea to be the shorter. Cooperating toward this end of symmetry is the intraocular pressure, which would tend to equalize inequalities of curvature, but which is erroneously named as a cause of them. A single or at least a usual and dominating cause for the lesser vertical curve is to be sought. Have we not overlooked this? Is it not evident that this physiologic, simple, and always present source of the mischief is lid-pressure? Those few varieties due to abnormalism of the lens, to traumatism, or to inflammatory diseases are, of course exceptions to this rule, evident, pathologic, and *sui generis*.

There is a striking clinical proof of this lid-pressure origin which I once showed in a paper on Albinism. If hyperopic, as the majority are, albinos have high degrees of astigmatism at axes 90° . The long continued and intense efforts to shut out the light by closure and pressure of the lids naturally results in a highly shortened radius at axis 90° . But what happens in the albino in a high degree and pathogenically, also happens in all human beings in a less degree, and physiologically. In the first volume of *Biographic Clinics* I suggested the existence of as many as a dozen distinct and co-operating mechanisms whereby the retina is shaded and the conditions of retinal sensibility preserved. I should have added another—the habitual position of the border of the upper lid, when the eye is “open,” just at the upper edge of the pupil. Indeed it commonly is below the upper limit of the pupil. The greater part of light either outdoors or indoors comes from above, the retinal image being formed by reflected light entering the pupil from below. The result is evident that the eyebrows, upper lid, and its lashes, act as shields against the light from above. This shielding is plainly one of the great requisites of clear retinal images and unexhausted retinal sensibility. All of this has much practical significance as to the methods of artificial illumination of our houses and public buildings, especially of our schools. Its ignoring is a fruitful source of social and educational evils. The highly necessary exclusion of the light from above is therefore chiefly brought about by the placing of the border of the upper lid so that it prevents the entrance to the pupil, in the usual head-position, of the light from above. In doing so it necessarily presses upon the cornea just above its cen-

tral or most important optical portion, and this pressure causes the shortening of its vertical curve which exists in nearly all eyes.

If the eye is hyperopic the usual astigmatism is at or near axis 90° , the shorter curve being vertical. If the eye is myopic, the great majority of axes are about 180° , the essential or anatomic condition as to the radii, remaining, of course, morphologically identical. In hyperopia the refracting power of the 180° meridian is artificially and positively made equal to that of the 90° meridian by the plus cylinder at axis 90° . In myopia conversely the shorter 90° meridian is made equal to the reverse meridian by the negative or minus cylinder at axis 180° . The total correction of the combined myopia and myopic astigmatism could of course be corrected by a high minus spherical lens, and the astigmatism then neutralized by a plus cylinder at axis 90° . As this would make a more bulky and heavy lens, it is practically better to use the minus cylinder combined with the minus spherical.

Dr. Bennett has shown that in presbyopes the plus astigmatisms at 90° tend to reversal and become those of 180° . No explanation has been offered of this fact so far as I am aware, but if it is true that the lid-weights and pressures are the preponderant physiologic causes of astigmatism, it follows that the change to 180° astigmatism in old age is due to lessened lid-pressure and lessened refraction power of the globe. The greater tension of the internal and external recti then come into play. Everyone knows that in the old the lids are less heavy and thick and tense owing partly to the absorption of their fat, etc. While seen through the ophthalmometer, the raising of the patients' lid by another, softly from the globe, will lessen the amount of astigmatism. One cooperating cause of lessened lid-pressure in the old is the retraction of the globe or lessened pressure upon the globe from behind, due to the absorption of orbital fat, etc., whence comes lessened refraction power and tendencies toward myopia, or 180° astigmatism. Another cooperating cause is probably lessened intraocular pressure in the old.

These facts and their explanation illustrate the fact of the continuous and retained resiliency of the cornea, and that the astigmatisms or variations from uniformity in its radii are caused by some agency external to the globe itself. In itself the cornea is or would be nearer an ideal contour than the vast number of astigmatic abnormalisms would at first sight seem to warrant. Operating alone the normal intraocular pres-

sure would prevent astigmatism. It is the effort to protect the pupil from light from above, and the eyeball and cornea from exposure, drying, light, injury, etc., which produces the morbid factor of astigmatism. Hence the silliness of the quackery which would abolish astigmatism by massage of the eyeball. If shadowing of the pupil were not necessary, if convergence and downward-looking were not demanded, if the lids could be taken away, if winking were abolished, if light and dust were not admitted, if tears were not needed for continually washing and lubricating the globe, etc., then astigmatism would be absent in the great majority of eyes.

In some animals we find an approximation to these conditions. Has any one studied the biology of the pupil, its shape, size, varying conditions, and functions, in different types of animals, and according to circumstances? Valuable lessons and suggestions would doubtless result. In the purest types of nocturnal animals, as the owl, there is no descent of the upper lid, the eye is always "wide open," and the pupil is in permanent mydriasis. The dazed condition of mind of this animal in the day is explained by its inability to form a useful retinal image, swiftly, and the resultant danger in flight. It will certainly have no astigmatism. There is the same wide retraction of the lids in the mixed night-prowlers, such as the cat, but there is provision for safe activity by day in the pupil narrowed to a vertical line. Astigmatism is also probably absent here. But the 90° line-like pupil is highly suggestive when the animal's habits and powers are considered. A glance through the illustrations of any book upon birds and animals with this thought in mind, is peculiarly illuminative. The conditions of the life and hunting-habits, for instance, of the birds, in relation to the visual function, governs the entire matter of the feathering and expression of the face. When the conditions are most difficult, as in the owls, the feathers are often arranged in two wide-flaring concentric radiating flattened circles of feathers, to give the eyes the greatest ease of seeing in all directions, especially desirable in a bird flying in the night, and among woods, etc. In the hawks and eagles this is not so necessary, and the upper lid and feathers may be used to shade the eye from above. In birds exposed to dangers from above, the upper lid must be completely retracted. In land animals the same law holds—the upper lid descends to shade the retina whenever the conditions and habits permit. The exophthalmos, or the retraction of the eyeballs, in all animals, also depends upon similar necessities

and conditions of living. In erect man the overhanging eyebrow and better shading of the eye by many mechanisms, is at last rendered possible, with higher visual function and judgment. But with the dropped upper lid, and its pressure upon the corneal border there is the production of the dangerous astigmatism! It is at least certain that one of the most valuable aids to the progress of civilization is the correction of the astigmatism of the modern man. Dr. Woodruff has written a most excellent and suggestive book, "*Effects of Tropical Light on White Men*," but a great modifying truth was omitted in the nonrecognition of the role of eye-strain, the effects optically and pathologicly upon the eye itself of tropical light. Almost every page of Dr. Woodruff's volume needs restatement from this standpoint. The incidence of disease, the peculiar social customs, as the midday siesta, clothing, etc., the mental and moral questions, gain a rephasing by an adequate conception of ocular physiology and pathology.

Observation shows that the lower lid has little effect in the origin of astigmatism. It does not rise in winking or sleep so much as the upper falls, and indeed hardly rises at all. This shows the dominance of the necessity of shading the pupil from the light from above. The function of the lower lid is a lessening one in our civilization in which we are looking downward more and more.¹ This more exacting demand for a finer outworking of the retinal function required that the shading lid-edge shou'd fall precisely so as to prevent the disturbing and wearying entrances of light from above. This descent and habitual accurate placing has brought its inevitable pathogenic astigmatism or bending of the vertical meridian of the cornea.

If the lower lid, as is evident, does not press against the cornea from below, as does the upper from above, it will follow that the sharper curve will be of the half above the center of the pupil. A peculiar type of irregular astigmatism must often result, and one which our symmetric astigmatic spectacle lenses and test-lenses will not neutralize. The thought is thrown out here in order that some one more capable than I may undertake an investigation and elucidation of the theory, and possibly devise lenses which will neutralize the varying refraction of such a cornea, greater above, and less below. If this variety of astigmatism exists it must follow that there is eyestrain unsuspected and uncorrected by our the lid-pressure is the chief cause of astigmatism and that the

(1) I have had one patient who could voluntarily raise the lower lid over the pupil without any descent of the upper.

some of our failures to cure in certain puzzling cases. That upper lid is the chief source of the phenomenon, as also that present cylindric lenses, and which may help to account for it produces an unequal degree of convexity above and below the center of the pupil, is demonstrated by a simple experiment. I have, for instance often found that a distant object, especially at night, and if made up, as outline letters and signs by electric lights,² can be seen much plainer by widely "opening the eyes." Conversely, by nearly closing the lids, the increased astigmatism soon shuts out the form of the letters.

One of the great mistakes made by oculists in the past has been the inexact diagnosis of the axes of astigmatism. It is strange, and even blameworthy, that all of us have not individually and collectively discovered that there are more astigmatisms than we had supposed at axes slightly different from the usual 90° and 180° . If we found them near these locations we negligently called them 90° or 180° , and thought no more of it. And hence the continuance of suffering on the part of many of our patients, and the failure to recognize fully a great truth which will eventually be seen to constitute one of the greatest of modern medical discoveries. One reason of our inexactness was that we allowed our patients while being refracted to sit with the head tilted from 5° to 20° , and this is the chief cause of our failure to locate certain axes of astigmatism with accuracy. By a simple test any one can demonstrate that these slightly variant axes necessitate an inclination of the head to one side in order to increase visual acuity. Long continued head-tilting in the young, whether from astigmatism directly, or from the morbid writing-posture, the result of visual necessities, produces secondary and compensatory lateral spinal curvature, and there are thousands of spines being thus morbidly curved. When the fact is clearly perceived, and when the role of preventive medicine is recognized, there will be a revolution in orthopedics, and the secret of thousands of medical cases of mysterious and persistent ill health will become clear. For spinal curvature, functional at first and for long, is a hundred times more frequent than the profession dreams. And in an erect animal like man, such a wrenching and twisting of the spinal column is productive of strange, far-away, and multiform diseases and symptoms. Innumerable patients are being treated unsuccessfully for these symptoms and effects, and the back is never looked at, the spinal abnormalism never suspected; and if recognized its

(2) The sign, e. g., "Pennsylvania Railroad," at the Jersey City railway station.

ocular origin would not be admitted. The trouble is functional for so many years that if posture and habits are not noted, and if refined methods of diagnosis are not instituted, the abnormalism would not be detected even if the hasty and superficial examination of the back should be made. As to therapeutics, all the massage, exercises, and physical culture methods that are devisable will not usually effect a cure so long as the head must be tilted in order to see plainly. If under the circumstances the spine is kept straight it will be accomplished at the expense of amblyopia and other kinds of injury and suffering due to eyestrain which nature evidently thinks are worse than scoliosis.

Why these axes of astigmatism slightly variant from "the rule" of 90° and 180° ? Every oculist has noted that when not thus at 90° or 180° the axes of the two eyes tend to be symmetric, i. e., if the right axis is 75° , 60° , 45° , etc., that of the left will be 105° , 120° , 135° , etc., respectively. They tend strongly to cluster about the vertical or horizontal meridians, and those beyond 20° away are very few. The origin and explanation of the fact I believe lies in the combined effect of convergence and what has been named *deorsumduction* or downward-looking, multiplied and intensified a thousand fold by civilization. Man is the only animal which has acquired a still doubtful parallelism of the axes of vision. The convergence demanded by civilization is not yet established as a habit or constant ability. But all reading, writing, and handworking requires a crossing of these axes at from 10 to 20 inches from the eye together with a habitual and synchronous depression of their planes from 20° to 50° . The natural result of these functions when combined is to incline the astigmatic axes caused by lid-pressure, normally at 90° in the hyperopic, either toward the nose or away from it, so that the prolonged axes would meet below, forming a letter V, or, above, the same letter inverted, or caret, Λ . The larger number of such symmetric axes are the caret axes in which with the right at 85° , 80° , 75° , 70° , etc., the left will be at 95° , 100° , 105° , etc.

If this symmetry is maintained, and if binocular vision is preserved, there will be no tilting of the head because any advantage in visual acuity gained in one eye by bringing the variant axis to 90° would be neutralized by the pronounced astigmatic blurring of the image of the other eye whose axis would be thus thrown further away from the 90° meridian. Besides this there is a psychic union or averaging of these

symmetric axes, which furthers what may be called the law of symmetric averages. The mechanism whereby these variant axes are symmetricized is thus almost always dominated by the lid-pressure acting as a constant force, but modified by the new factors that come into play with combined convergence and deorsumduction.

What are these modifying agencies? The chief is probably the action of the obliques in rotating the eyeballs under the new and great exaggerations of combined convergence and downward-looking demanded by civilized life. Another may prove to be the relative points of insertion of the recti muscles also concerned in the new morbid task of combined convergence and downward-looking, and the resultant variations of trends of the traction, followed by tilting of the astigmatic axes, modified by and coupled with the interference with free movement of the eyeballs by the nasal bones and shape of the orbit. A skull illustrates this anatomically, and physiologically it is demonstrated by asking a patient to fix upon an object held at the extreme near-point with axes of vision horizontal and then observing the difficulty or impossibility of transfixing the object when it is depressed 40° below the horizontal. This cause of the switching of the normal 90° axes thus becomes clear. It need only to be noted that civilization with its myriad kinds of "near-work" especially reading and writing, has tremendously increased this need of combined convergence and downward-looking, and at a time of life, during youth and school days, when the accommodation is great, the book or writing held close to the eye, and when the cornea is most plastic. The practical lessons to be deduced from the fact are thus:

1. The greatest care necessary in diagnosing these slightly variant axes with the 20 foot tests.

2. The duty, frequently of an equally careful retesting the location of the axes at the reading distance. It will be found sometimes that the amount of the astigmatism will not differ at the two ranges, but that the axes will not be the same at 14 inches as they were, and are, at 20 feet. Thus a prescription differing in the axes of astigmatism may be required in the two sets of lenses for distance and near spectacles. This may rarely be the reason why bifocal lenses cannot be ordered, as these require the same axes in both the near and distance lens. It may also account for the inexplicable dissatisfaction and eyestrain which sometimes persists in reading and writing after the most careful correction has been made.

although usually this undoubtedly is due to the common, yet commonly overlooked subnormalism of accommodation.

3. The wisdom of holding the book as nearly on a level with the eyes as may be, and of sharply pitched desks in writing, whereby the writing paper may be placed opposite the right shoulder. Writing with low and level tables or desks compels the writer to get above and look down upon, instead of off at, his writing, and produces the major part of the 27 percent of the lateral scoliosis of school children.

4. The placing of the habitual reading and writing focus at a point critically designed to make it as far as possible without running into the other danger of producing a wearying and physiologically expensive small image upon the retina. This must be decided upon after careful consideration of personal habits, kinds of near work done, the size of the print, chirography, sewing, etc., customary with the patient; the amblyopia present, the natural acuteness of vision, etc., must also be taken into account. We should, therefore, urge upon patients the use of large, well rounded letters in writing, good black inks, good paper, and the rest, as well as the vertical handwriting always to be emphasized. In general, both upon the patients personally, and persistently upon the public, we should in season and out of season, advise the use of large type, as large as may be, the blackest and best printer's ink, wide spaces between the lines, and opaque paper with dead surface. This will enable us to focus the reading glasses at a greater distance, say 16 inches, than is possible with print, paper, etc., that compel a reading distance of 10 to 12 inches. The special application of this rule to needlewomen, typewriters, musicians, artists, mechanics, handicraft-workers, and others, need not be described.

Intermediate between the regular and symmetric astigmatisms and those showing complete asymmetry may be placed an odd variety that belongs to neither class exclusively, and which exhibits traits of both. These are such anomalies as the following:

- a. Both axes of hyperopic astigmatism at 180° .
- b. Both axes of myopic astigmatism at 90° .
- c. One axis of hyperopic astigmatism at 90° , while that of the other eye is at 180° .
- d. One axis of myopic astigmatism at 180° , while that of the other eye is at 90° .

e. One axis of hyperopic astigmatism at any variant, while that of the other eye is at right angles to it, as e. g., one at 75° the other at 165° .

f. The same as regards myopic astigmatism.

All these types bear witness to a common cause, the lid-pressure, chiefly, acting with a different incidence in the two eyes, and specially modified perhaps by many conditions, such as orbital shape and space, habits and necessities of work, one-sidedness of function or exposure, relative amblyopia of the two eyes, insertions of the extraocular muscles, and others. One may sometimes detect a difference in the physiologic tightness or closeness of the lids of the two eyes in relation to the globes.

There remain the frankly unsymmetric varieties. We have excluded those few due to tumors, traumatism, surgical operation, and the direct action of inflammations of the cornea and conjunctiva. Among those of this class too little attention has been given to those resulting from lid-diseases. A meibomian cyst will warp the cornea and temporarily at least change either the amount or the axis of astigmatism undetected. Palpebral conjunctivitis, incipient granular lids, localized or general in one eye more than another, may increase the lid-pressure and thus specially modify the relative astigmatism. Such inflammations or hyperemias may no longer exist but their effects still remain and show as relative differences in lid-plasticity thickness, smoothness, weight, etc. Relative variations in exophthalmos or retraction of the two eyes, in "puffiness" of the lids from albuminaria, are among other possible causes of these variations.

Of true asymmetric astigmatisms the most important class is that made up of those which compel a tilting of the head, (with resultant spinal curvature), in order to see more plainly and especially to see printed letters more distinctly.³ If the axis of astigmatism of the dominant eye varies from 90 or 180 by 5, 10, 15, or 20 degrees while that of the nondominant eye is unsymmetric the patient must incline the head to a cor-

(3) See "Torticollis and Spinal Curvature," *American Medicine*, March 26, 1904; "Malposition of the Head, etc., *ibid.*, May 21, 1904; "Dextrality and Sinistrality," *Popular Science Monthly*, August, 1904, and "The Pathologic Results of Dextrocularity and Sinistrocularity," *Ophthalmology*, October, 1904; "The Optic and Ocular Factors in the Etiology of the Scoliosis of School Children," *American Medicine*, April 8, 1905; "Visual Function, etc.," *Medical Record*, April 22, 1905.

responding degree in order to see print or vertical handwriting plainly. He tilts the head to the right when that is required to bring his ocular axis to 90° or 180° and to the left when conversely that is required by the peculiar axis to bring it into alignment with the normal 90° or 180° . The larger number tilt to the right because most of the young are hyperopic, (the astigmatisms of the eyes are generally at or near 90°), and lastly, because, when variant from 90° , the great majority of the right or dominant eye variants are at 75° or 80° . When the variation is further than 20° from 90° , the tilting would become too pronounced and impracticable, other morbid results then follow. In addition to or modification of this law I have lately discovered that head-tilting may be caused by another kind of unsymmetric astigmatism: if, for instance, the axis of the dominant eye is 55° , and that of the other is 105° , there is a partial neutralization of the asymmetry, but there is left a residuum of 10° , which will require a corresponding inclination of the head to the right to produce the effect upon the mind of a 90° axis of the dominant eye. This may be called the law of unsymmetric astigmatic averages in dominance. It is a corollary of the law of symmetric averages alluded to.

Astigmatisms that do not group themselves in any of the preceding classes exist, and can only be explained as individual variations produced by some cause differing usually from those in other cases, the result of some old inflammation, of injury, of heterophoria, amblyopia, or ametropic strain, etc.

The general reason for the slight differences in the tilting of the axes hardly needs mention. There is nothing absolutely symmetric in biologic structures. The eyes are never on the same level, or equidistant from the nose, the orbits never exactly alike, the insertions of the muscles never mathematically the same, the nasal bones vary in width, height, contour, etc.; when such variations are of a certain degree or peculiarity they modify the results of the constantly acting cause, or lid-pressure, and bring about small abnormalisms of astigmatism in numerous ways.